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Test of a Fan System of Ventilation for Dairy Barns

By M. A. R. Kelley

Mem. A.S.A.E. Barn Architect, Division of Agricultural Engineering, Bureau of Public Roads, U. S. Department of Agriculture. Member A.S.A.E. Subcommittee on Farm Building Ventilation

THE test reported in this article is one of a series of tests conducted by the writer during the winter of 1920-21 on a number of farm building ventilating systems in different states. The object of the investigations was to determine the factors which influence the operation of barn ventilating systems. The tests were made in cooperation with the subcommittee on Farm Building Ventilation of the American Society of Agricultural Engineers and with the assistance of several of the state agricultural experiment stations.[1]

The forced draft system has been used in the ventilating of public and commercial buildings for a number of years. It is only during the past few years that it has been tried in dairy barns. The circulation of air in this barn was obtained by the use of a fan connected with an electric motor. Since there are very few fan systems used in the ventilation of barns at the present time, a report of this test will, no doubt, be of considerable interest to agricultural engineers and others interested in the ventilation of farm buildings.

The installation of such systems is necessarily limited to buildings where suitable power can be obtained and at such rate that the operation and maintenance cost is not excessive. While ventilation systems as now installed in dairy barns primarily are used for ventilation during cold weather, the fan system is sometimes used to increase the circulation of air during the summer days of high temperature. Keeping the cows at a comfortable temperature and free from flies materially aids in maintaining the summer milk flow. However, the number of barns in which such an arrangement can be used economically is limited.

The system described in this article was newly installed in the South Dakota agricultural experiment station dairy barn, at Brookings, and was tested during the middle of January, 1921. The weather during this time was quite mild especially for this locality.

The barometer gradually fell during the first part of the test and during the last half rose again so that it was practically the same at the end of the test as at the start.

The wind velocity increased during the first half and decreased during the latter half. Unfortunately the records of wind velocities are not complete as the anemometer developed a short circuit in the electrical indicating apparatus during the third period reading. Although it was not possible to obtain an exact reading for this period, it was observed that the force of the wind was gradually increasing, approximately as shown by the dotted line on the chart.

The roof of the barn was of the full monitor type and in plan the building was I-shaped. The main part of the barn was protected on the northeast and northwest sides by sheds, and the horse and feed-storage barn was placed across the south end, thus forming a sheltered court on the east and west sides of the cow stable. (Figs. 1 and 2.)

The windows were 12-light (10 x 12) double hung, and were provided with storm sashes on the north and west sides. The window sashes fitted comparatively tightly into the frames while there was a considerable leakage through

[1]The writer was assisted by C. S. Whitnah, of the King Ventilating Company, Owatonna, Minnesota, a member of the Subcommittee on Farm Building Ventilation. R. L. Patty, also a member of this subcommittee and extension specialist in agricultural engineering at the South Dakota State College of Agriculture, made arrangements for the installation and assisted during part of the test.

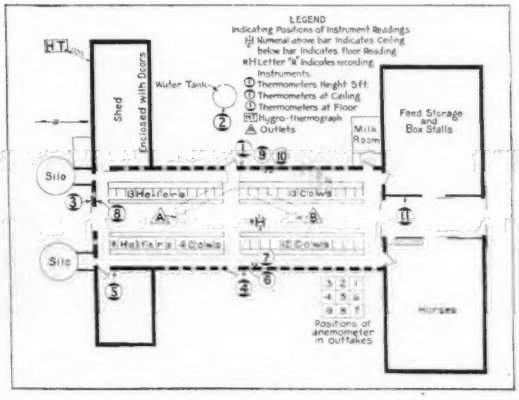


Fig. 1, at left, shows the exterior of the building group embracing the barn under test. Fig. 2 shows the group in plan

the Dutch doors on the east and west sides.

The walls were of frame construction with drop siding on 2-by-6-inch studs and ceiled with ⅞-inch dressed and matched lumber with building paper on both sides of the studs. About one half of the mow floor was well covered with straw while the balance was bare. (Fig. 3.)

The barn was well filled with stock, consisting of 29 mature cows and 21 head of young stock.

A number of years ago Romeaux established the law that heat produced by animals is proportional to the two-thirds power of their live weight. Armsby and Kriss have used this law in estimating the amount of heat given off by dairy cows of various weights under average conditions. Armsby has also shown that the amount of carbon dioxide given off by animals is in proportion to their heat production.[1] Hence, the heat production may be used as an approximate means of estimating the amount of circulation required for maintaining any desired standard of ventilation in stables. Using these data as a basis it was found that the total average heat produced in this barn (136,700 B. t. u. per hour) is equivalent to the average heat produced by 45.5 cows weighing 1000 pounds. The cows were generally heavy milkers. The 27 head, including three strippers, gave 459 pounds of milk per day during the test.

Fig. 3 shows the position of outtake flues built of shiplap and on the mow floor. The fan housing encloses a 24-inch electric fan. The motor was rated ¼ horsepower, 850 revolutions per minute, and 220 volts. The fan housing is shown where the two outtakes converge and opens to the air just below the roof plate. The motor is enclosed in a special casting and is cooled by drawing air through a by-pass which is open to the outside air. The outer opening of the fan casting is fitted with weighted shutter vanes so actuated that they close when the fan is not running. Two small sliding doors, 11 by 13 inches, one above each flue at the point of connection with the fan box, provides a means of decreasing the amount of air drawn through the flues. Opening these doors kills the draft at the lower end of the flues and reduces the volume of air drawn from the stable. It was found that by opening the doors fully the amount of air drawn from the stables could be decreased approximately 27 per cent.

Fig. 4 shows the lower end of the outtake flues as they appear in the dairy barn. They are hinged at the ceiling so that they may be drawn up out of the way in order to facilitate cleaning the barn. This picture also shows the hygrometers at the floor and ceiling in the center of the barn. The air about the hygrometers was circulated by means of a fan in order to obtain uniformity of air condition. The normal size of the outtake flues is 20 by 20 inches, inside dimensions, with an effective area of 2.77 square feet of each flue. The horizontal length of flue A (Fig. 2) on the mow floor is 26.5 feet, while flue B is two feet longer. The length of each flue below the ceiling is the same.

It was impossible to secure data on continuous readings as the barn was used during the daytime for experimental and class work necessitating discontinuing the tests during the daytime. The readings were started after the barn was closed up in the evening and continued throughout the night, as shown in the chart and Table II. Readings of all instruments were taken every three hours.

A set of ten readings of the air movement in each flue was made at each period. The opening of each flue was divided as shown in Fig. 2, the anemometer readings being taken at the center of each square. The tenth reading was made about 30 inches up the flue at center. This was done in order to ascertain which position would give the best average reading for the flue and produced some interesting data. Table I shows the results of these various readings for the first and second day and their average.

It will be noted that the average sum of the readings (Table I) in flue A in positions 5 and 10 equals 450, while the average for all positions for the first day is 448. On the second day the average of the sum of the readings in positions 5 and 10 was 568, and the average for all readings for the same day was 590. It will be noted that in flue B the average sum of the readings for positions 5 and 10 on the second day equals 593, and the average for all positions on

[1] A complete report of this is given in the *Journal of Agricultural Research*, of June, 1921, and reprinted in the August, 1921, number of AGRICULTURAL ENGINEERING.

TABLE I—VELOCITY OF AIR MOVEMENT IN FLUE IN FEET PER MINUTE

	1	2	3	4	5	6	7	8	9	10	Average
FLUE A											
Position											
First day	458	436	477	430	389	421	502	418	431	511	418
Second day	603	624	580	582	536	611	580	572	604	601	590
Average	530	530	528	506	462	516	541	495	517	556	519
FLUE B											
Position	1	2	3	4	5	6	7	8	9	10	Average
First day	444	450	451	481	398	454	517	...	...	...	459
Second day	598	586	620	587	539	591	599	574	572	647	591
Average	521	518	535	534	468	522	558	...	...	...	525

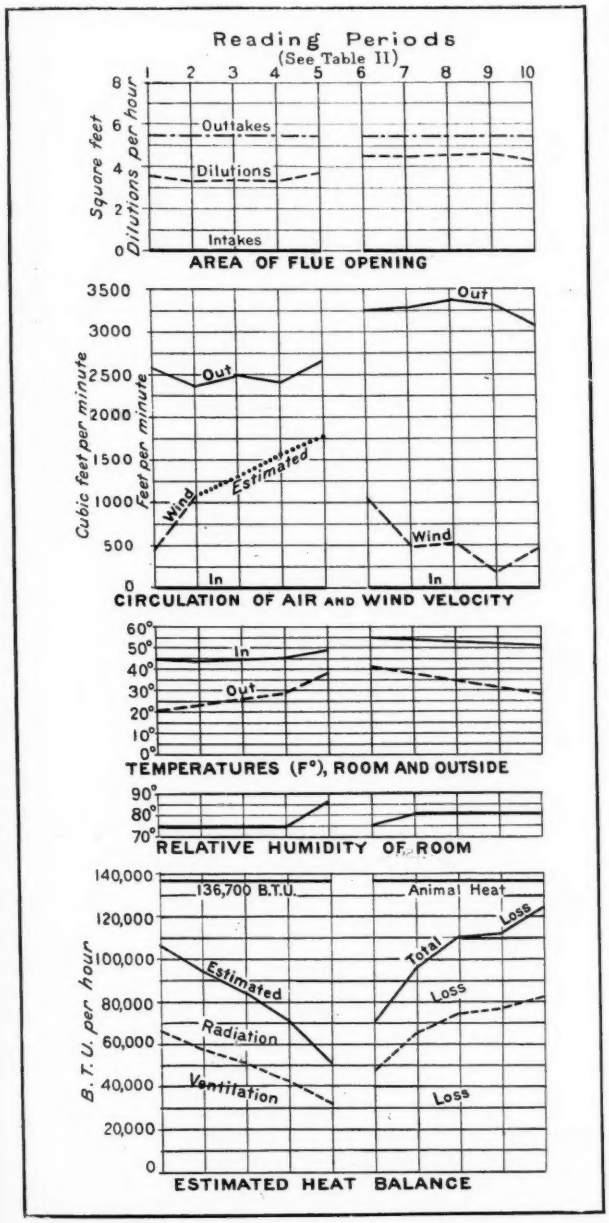
TABLE II—READINGS TAKEN DURING THE TEST

Flue area: A, 2.77 sq. ft.; B, 2.77 sq. ft.; total, 5.54 sq. ft. Flue A was 2 feet longer than B.

Period Reading No.	Time	Air Movement: Velocity Feet Per Min.—Average A	B	Total Volume Cubic Feet Per Min.	Dilutions Per Hour	Wind Velocity —m.p.h.	Average Temperature: In	Out	Diff.	Humidity—%	Barometer	Wind Direction
1	8:00 p. m.	480	448	2570	3.6	5.0	44.3	21.5	22.8	74.0	28.38	South
2	11:15 p. m.	402	464	2398	3.3	12.0	43.6	22.5	21.1	74.0	28.34	South
3	2:00 a. m.	439	457	2481	3.4	Out of	44.6	26.5	18.4	74.0	28.20	Southwest
4	5:10 a. m.	442	433	2423	3.3	Order	45.5	29.5	16.0	74.0	28.04	.....
5	7:45 a. m.	476	496	2692	3.7	20.0	49.2	38.5	10.7	87.5		.....
Average		448	459	2513	3.4	12.3	45.4	27.7	17.8	76.7	28.24	.....
					SECOND DAY							
6	7:00 p. m.	596	580	3257	4.5	12.0	55.1	42.2	12.9	75.5	28.12	Southwest
7	10:25 p. m.	592	589	3271	4.5	5.3	54.8	37.2	17.6	80.5	28.26	Southwest
8	1:20 a. m.	608	618	3395	4.6	6.0	53.6	33.2	20.4	80.0	28.29	Southwest
9	4:10 a. m.	595	612	3343	4.6	2.0	52.0	31.8	20.2	80.5	28.34	South
10	7:00 a. m.	560	560	3102	4.3	5.5	51.8	28.2	23.6	80.0	28.36	Southeast
Average		590	591	3274	4.5	6.1	53.4	34.5	18.9	79.3	28.27	.....
Average readings of all		519	525.7	2893	3.9	9.2	49.4	31.1	18.3	78.0	28.25	.....

Fig. 3. Arrangement of outtakes and fan housing

Fig. 4. Interior of stable showing hinged outtakes



that day was 591. It was not possible to secure the average for positions 8, 9, and 10 on the first day as the power went off before the eight o'clock set of readings were completed. In calculating the amount of ventilation on this day average conditions were assumed for the missing readings. The average of readings for flue A at position 5 for both days was 83 per cent of the reading given in position 10 which was 30 inches above position 5, and the same difference occurs in flue B on the second day. In order to find some reason for this condition a smoke test was made and it was found that the air on all sides of the flue came down on the outside and entered the flue in the form of a cone, hence, we can assume that the reading at position 10 was higher because of the fact that it was nearer the apex of the cone formed by the incoming air.

There was some variation in the direction of the wind close to the barn, but the general direction was as recorded in Table II. It will be noted that the wind velocity reading is greater on the first day and that the direction was mostly in opposition to the draft of the fan while the second day the wind shifted so that it probably aided the effectiveness of the fan, as the ventilation was greater the second day with a lower average wind velocity. This is a natural assumption, but we do not have definite data as to whether the speed of the fan was constant throughout the tests although it is believed that the speed of the fan was fairly constant and would average up.

In referring to the amount of ventilation (Table II) the term "dilutions (of air) per hour" is preferred to "number of changes of air per hour." The air is not completely replaced by fresh air, but part of the foul air in the room is forced out and the incoming air having a lower percentage of carbon dioxide mixed with the stable air of a higher percentage of carbon dioxide thus decreases the carbon dioxide content by dilution. The inside dimensions of this barn were 39 feet 4 inches by 112 feet 4 inches. The total volume of the room was 43,495 cubic feet. In calculating the volume of the room, the variations in heights of the litter and feed alleys were measured with more care than is usual in roughly estimating the volume of a room. The height of the ceiling at the feed alleys was nine feet and at the center of the driveway ten feet two inches. The cows in this barn faced out (Fig. 4). With reference to Table II, it will be noted that the average number of dilutions per hour was three and four tenths (3.4) for the second day. Assuming that the average speed of the fan was the same for both days, the wind speed and direction made some difference in the amount of ventilation secured.

It will be noted that the temperatures during this test were very mild, especially so for winter weather in this locality. The lowest outside temperature, 21.5 degrees, was recorded at the beginning of the first day's test and the highest, 42.2 degrees, at the beginning of the second day's test.

The average for the two days was slightly less than freezing. Reference to the accompanying charts shows that the variation of temperature throughout each day's test was quite gradual for each period.

The average ceiling temperature for the two days was 50.7 degrees, the floor temperature 47.7 degrees, and the average room temperature 49.4 degrees. The variation in the inside temperature during these periods was also gradual. It is regrettable that the weather conditions were not more severe in order that we might have been able to test the system under conditions existing with the average winter weather experienced in this locality and the effect it would have had on ventilation in attempting to control the temperature in the barn.

Since Armsby has provided a means of estimating the approximate amount of heat given off by cows under average conditions of care and feed, it is interesting to note with reference to the chart how the temperature varied; as the total heat lost by ventilation and radiation decreased, the temperature inside increased. The outside temperature also increased and undoubtedly was the largest factor influencing the inside temperature. The radiation and ventilation losses were calculated in accordance with the best engineering practices. The total heat given off by animals was estimated using Armsby's data as a basis. The total amount of heat given off by animals is the sum of the heat generated by each and is based upon their individual weights and not upon the heat produced by an animal of the average weight of the cows in the herd multiplied by the number of cows. It is estimated that in this barn 43.7 per cent of the heat generated by the animals was lost by ventilation and 23.5 was lost by radiation. The balance less any leakage loss was available for warming the room. These percentages are true for this test and for the conditions in this barn at the time, and the reader is cautioned against applying these heat loss percentages to any other barn. It should be remembered that the ventilation in this instance was secured by mechanical means.

Other interesting facts in regard to the heat balance will be brought out in the summary of the winter's tests in a later report.

Since the ventilation was secured by mechanical means a report would not be complete without data in regard to the cost of operation. An electric meter of a type commonly used in measuring the amount of electric current consumed was used in this test. Since a meter was not available at the beginning of the test the exact amount of current used cannot be stated. However, it was possible to ascertain the amount of current used during the continuous run of 14¼ hours on the second day, and this may be used as representative of the entire test. The total consumption of electric current for this period was 2.3 kilowatt hours, or at the rate of 0.16 kilowatt per hour.

Tests for Rating Grain Threshers*

THERE is little uniformity in the rating or recommendations with respect to the power consumed or the capacity of most belt driven machines. The rating or recommendation given grain threshers, for instance, is sometimes grossly misleading and often results in direct or indirect loss to the purchaser as well as to the farmer he does work for. With insufficient power it is very difficult to do a good job of threshing and save the grain because of the uneven motion which results, besides it is hard on the entire outfit which means a rapid deterioration of both separator and tractor.

Take for instance the power recommended for driving grain threshers as given by the manufacturers for 20 and 22-inch-cylinder machines with all attachments. This is from 15 horsepower for some machines to 30 horsepower for others. The power recommended per inch width of cylinder varies as much as 175 per cent. The bushel capacity per horsepower hour, which should be fairly uniform, varies all the way from 2½ to 6 bushels, with an average of approximately 3 or a little over.

However inconsistent these figures may be, they are not exactly wrong because it is probable that they may be applicable or have even based upon actual results under certain conditions. There is no one to blame for the situation. It is merely a condition that has been brought about in the commercial pursuance of the industry and has gone so far without a proper solution.

Before the advent of the farm tractor, the situation was different for several reasons. First, practically all the threshing was done with steam outfits and most of the separator manufacturers also made the steam engines to operate these machines, with the results that the two were pretty well matched regardless of the rating. The complete outfit was generally of one make.

The great part of threshing was then done by custom threshers, most of whom had considerable threshing experience before they purchased their machines.

The number of machines in use at that time was considerably less than now and the season was longer resulting in greater specialization. The poor work then was more generally because of carelessness in operation or over-crowding. The custom thresher, if he gained a bad reputation, was automatically eliminated or was forced to hire competent operators, but the farmer who makes a bad selection usually tries to get along the best he can with his own threshing and that of some of his neighbors.

The situation is not easy of solution. If a uniform rating or recommendation could be adopted, it would not altogether solve the problem, although it would be a great help. Threshing conditions vary so that the application of the rating would have to be determined for different conditions. It also seems hopeless at this time to attempt to standardize those conditions or to formulate a method of testing these machines upon which a standard rating or recommendations can be based which would be practical and easily performed and they would have to be both to be acceptable to manufacturers.

Some tests are essential. Without tests we cannot gain experience. There is nothing to learn and we can have no issue. So far there have been very few tests of any kind conducted on grain threshers outside of those made by manufactures. This is also true of ensilage cutters and feed mills.

The object of such tests would be first of all to determine the power required to operate the machines under different conditions and in different kinds of grains and then to determine a fair capacity under the same conditions, wastage of grain, etc.

These tests would be bound to result in a great deal of good for all concerned. They will automatically solve the question of rating and eventually bring about more uniform rating of these machines. If made in various parts of the country, some valuable data would be obtained with respect to different kinds of grain and conditions. The advantage to the agricultural industry to be derived from such work is sufficiently great apparently to warrant more effort along this line being made by the proper departments of the agricultural colleges.

*From the report of the A. S. A. E. Committee on Farm Power Machinery for 1919.

The Design of Outtake Flues for Stable Ventilation

By J. L. Strahan

Mem. A.S.A.E. Department of Rural Engineering, Massachusetts Agricultural College

FOR a number of years past it has been considered that the amount of air which should pass through a stable housing dairy cattle in order to maintain a proper degree of purity to the air is 69 cubic feet per minute per head of stock. This is merely another way of stating King's standard that not more than 3.3 per cent of the total amount of air in the room should be once breathed. Such air would contain 16 or 17 parts of carbon dioxide per 10,000, assuming that air coming from the lungs contains about 425 parts and pure air only 3 or 4 parts.

It has also been the practice to attempt to maintain this standard or at least to approximate it by means of a natural draft system which depends solely upon animal heat for its motive power. One of the purposes of this article is to discuss the possibility of attaining this end, and to justify certain assumptions which can be used to derive a formula which will be as simple as possible and still remain an adequate expression for the proper design of outtake flues.

It is a self-evident fact that, with the exception of the latent heat of vaporization, or that heat which holds the exhaled moisture in vapor form, all of the heat produced by stock in a closed room will be used either to warm the air passing through the room or else will be lost through the walls by radiation and conduction. It is reasonable, therefore, to state the heat conditions in formula form as follows:

(1) $H=D\ (.01848\ N\ V\ +h)$, in which H=total heat produced in B. t. u. per hour,

D=degrees of temperature difference between outside air and stable air,

N=number of cows,

V=volume of air required per cow per hour in cubic feet,

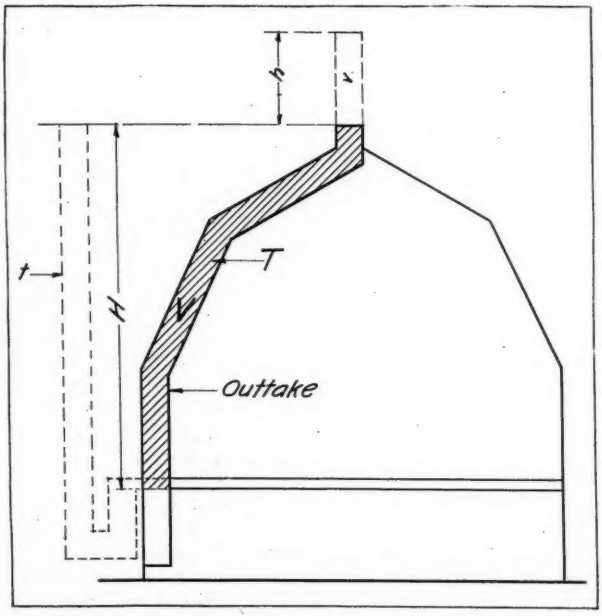


Diagram showing essential dimensions of outtakes

.01848=B. t. u. required to raise one cubic foot of air through one degree Fahrenheit, or the product of .231 (specific heat of air) and .08 (weight of a cubic foot of air), and h=heat lost through walls in B. t. u. per hour per degree of temperature difference.

This formula may be algebraically transformed into either of the two following forms:

$$(2)\quad D=\frac{H}{.01848 \times N \times V + h},$$

which can be used to determine the limiting temperature difference for a given stable that will maintain a given standard of air purity, or

$$(3)\quad V=\frac{H-Dh}{.01858 \times D \times N},$$

which can be used to determine the volume of air that can be passed through a given stable maintaining a given temperature difference.

The application of these formulae requires that the heat produced and the heat lost be known. To supply this data the following tables are prepared showing, first, the heat produced by dairy cows under different conditions and, second, the value for K, or the rate of heat transmitted in B. t. u. per hour per square foot for walls of various designs.

TABLE 1.—HEAT AVAILABLE FOR VENTILATION PRODUCED PER HOUR BY DIFFERENT BREEDS OF COWS UNDER DIFFERENT CONDITIONS

Breed	Condition	Calories of Heat Produced Per Hour (Armsby and Kriss)	B.t.u. Produced Per Hour
	Maintenance	306	1214
Jersey	20 lbs. milk	509	2020
	30 lbs. milk	571	2266
	Maintenance	381	1512
Holstein	30 lbs. milk	622	2468
	45 lbs. milk	700	2778

The figures in this table are computed from tables given in the paper entitled "Some Fundamentals of Stable Ventilation," by Armsby and Kriss, in the "Journal of Agricultural Research," June, 1921. (This paper was reprinted in the July and August, 1921, numbers of AGRICULTURAL ENGINEERING.)

TABLE 11.—VALUE OF K FOR COMPUTING HEAT LOSS THROUGH WALLS OF DAIRY STABLES

TYPE OF CONSTRUCTION	Value of K
Concrete—12 inches thick (solid)	.30
Concrete—8 inches thick (solid)	.40
Concrete—6 inches thick (solid)	.56
Stud Wall—(ceiled inside, double boarded, and papered outside.)	.25
Glass in windows—1 thickness	1.00
Glass in windows—2 thickness	.50

The figures in this table were computed from tables given in "Heating and Ventilating," by Hoffman, and "Heating and Ventilating Buildings," by Carpenter.

Applying these formulae to a specific case, the results will be somewhat as follows: Let us assume a stable 36 by 80 feet inside measurements housing forty cows, the walls being 8 feet high to the eaves and consisting of twelve inches of

The average for the two days was slightly less than freezing. Reference to the accompanying charts shows that the variation of temperature throughout each day's test was quite gradual for each period.

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Before the advent of the farm tractor, the situation was different for several reasons. First, practically all the threshing was done with steam outfits and most of the separator manufacturers also made the steam engines to operate these machines, with the results that the two were pretty well matched regardless of the rating. The complete outfit was generally of one make.

The great part of threshing was then done by custom threshers, most of whom had considerable threshing experience before they purchased their machines.

The number of machines in use at that time was considerably less than now and the season was longer resulting in greater specialization. The poor work then was more generally because of carelessness in operation or over-crowding. The custom thresher, if he gained a bad reputation, was automatically eliminated or was forced to hire competent operators, but the farmer who makes a bad selection usually tries to get along the best he can with his own threshing and that of some of his neighbors.

The situation is not easy of solution. If a uniform rating or recommendation could be adopted, it would not altogether solve the problem, although it would be a great help. Threshing conditions vary so that the application of the rating would have to be determined for different conditions. It also seems hopeless at this time to attempt to standardize those conditions or to formulate a method of testing these machines upon which a standard rating or recommendations can be based which would be practical and easily performed and they would have to be both to be acceptable to manufacturers.

Some tests are essential. Without tests we cannot gain experience. There is nothing to learn and we can have no issue. So far there have been very few tests of any kind conducted on grain threshers outside of those made by manufactures. This is also true of ensilage cutters and feed mills.

The object of such tests would be first of all to determine the power required to operate the machines under different conditions and in different kinds of grains and then to determine a fair capacity under the same conditions, wastage of grain, etc.

These tests would be bound to result in a great deal of good for all concerned. They will automatically solve the question of rating and eventually bring about more uniform rating of these machines. If made in various parts of the country, some valuable data would be obtained with respect to different kinds of grain and conditions. The advantage to the agricultural industry to be derived from such work is sufficiently great apparently to warrant more effort along this line being made by the proper departments of the agricultural colleges.

*From the report of the A. S. A. E. Committee on Farm Power Machinery for 1919.

The Design of Outtake Flues for Stable Ventilation

By J. L. Strahan

Mem. A.S.A.E. Department of Rural Engineering, Massachusetts Agricultural College

FOR a number of years past it has been considered that the amount of air which should pass through a stable housing dairy cattle in order to maintain a proper degree of purity to the air is 69 cubic feet per minute per head of stock. This is merely another way of stating King's standard that not more than 3.3 per cent of the total amount of air in the room should be once breathed. Such air would contain 16 or 17 parts of carbon dioxide per 10,000, assuming that air coming from the lungs contains about 425 parts and pure air only 3 or 4 parts.

It has also been the practice to attempt to maintain this standard or at least to approximate it by means of a natural draft system which depends solely upon animal heat for its motive power. One of the purposes of this article is to discuss the possibility of attaining this end, and to justify certain assumptions which can be used to derive a formula which will be as simple as possible and still remain an adequate expression for the proper design of outtake flues.

It is a self-evident fact that, with the exception of the latent heat of vaporization, or that heat which holds the exhaled moisture in vapor form, all of the heat produced by stock in a closed room will be used either to warm the air passing through the room or else will be lost through the walls by radiation and conduction. It is reasonable, therefore, to state the heat conditions in formula form as follows:

(1) $H=D\ (.01848\ N\ V\ +h)$, in which H=total heat produced in B. t. u. per hour,

D=degrees of temperature difference between outside air and stable air,

N=number of cows,

V=volume of air required per cow per hour in cubic feet,

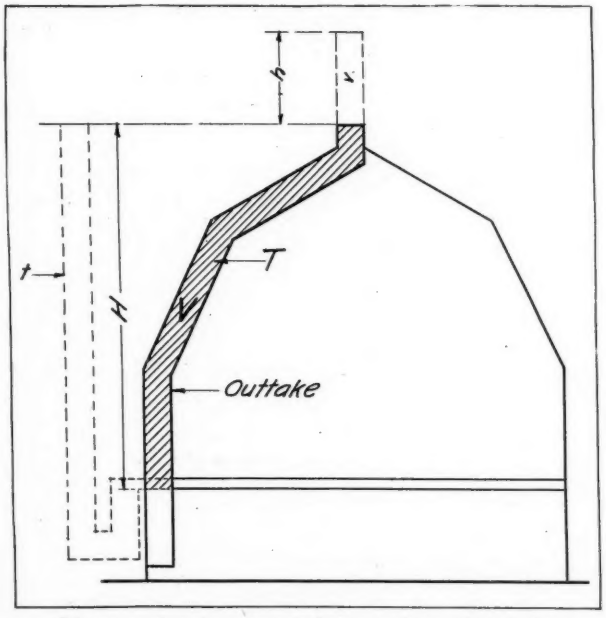


Diagram showing essential dimensions of outtakes

.01848=B. t. u. required to raise one cubic foot of air through one degree Fahrenheit, or the product of .231 (specific heat of air) and .08 (weight of a cubic foot of air), and h=heat lost through walls in B. t. u. per hour per degree of temperature difference.

This formula may be algebraically transformed into either of the two following forms:

$$(2)\quad D=\frac{H}{.01848 \times N \times V + h},$$

which can be used to determine the limiting temperature difference for a given stable that will maintain a given standard of air purity, or

$$(3)\quad V=\frac{H-Dh}{.01858 \times D \times N},$$

which can be used to determine the volume of air that can be passed through a given stable maintaining a given temperature difference.

The application of these formulae requires that the heat produced and the heat lost be known. To supply this data the following tables are prepared showing, first, the heat produced by dairy cows under different conditions and, second, the value for K, or the rate of heat transmitted in B. t. u. per hour per square foot for walls of various designs.

TABLE 1.—HEAT AVAILABLE FOR VENTILATION PRODUCED PER HOUR BY DIFFERENT BREEDS OF COWS UNDER DIFFERENT CONDITIONS

Breed	Condition	Calories of Heat Produced Per Hour (Armsby and Kriss)	B.t.u. Produced Per Hour
	Maintenance	306	1214
Jersey	20 lbs. milk	509	2020
	30 lbs. milk	571	2266
	Maintenance	381	1512
Holstein	30 lbs. milk	622	2468
	45 lbs. milk	700	2778

The figures in this table are computed from tables given in the paper entitled "Some Fundamentals of Stable Ventilation," by Armsby and Kriss, in the "Journal of Agricultural Research," June, 1921. (This paper was reprinted in the July and August, 1921, numbers of AGRICULTURAL ENGINEERING.)

TABLE 11.—VALUE OF K FOR COMPUTING HEAT LOSS THROUGH WALLS OF DAIRY STABLES

TYPE OF CONSTRUCTION	Value of K
Concrete—12 inches thick (solid)	.30
Concrete—8 inches thick (solid)	.40
Concrete—6 inches thick (solid)	.56
Stud Wall—(ceiled inside, double boarded, and papered outside.)	.25
Glass in windows—1 thickness	1.00
Glass in windows—2 thickness	.50

The figures in this table were computed from tables given in "Heating and Ventilating," by Hoffman, and "Heating and Ventilating Buildings," by Carpenter.

Applying these formulae to a specific case, the results will be somewhat as follows: Let us assume a stable 36 by 80 feet inside measurements housing forty cows, the walls being 8 feet high to the eaves and consisting of twelve inches of

concrete to the window sills 3½ feet above the floor, and framed from this point to the plate, using 2-by-6-inch studs ceiled inside, and sheathed, papered and sided outside. The window space provides 4 square feet of single glass area per cow. Assume also that the cows are Holsteins producing 45 pounds of milk per day per cow.

Under these conditions, the value of

H=40 x 2778=111, 120 *B. t. u.* per hour

h=(232 x 3.5) x .30 + (4 x 40 x 1) + (232 x 4.5)—(4 x 40) x .25=634 *B. t. u.* per hour per degree temperature difference

V=3452 (Armsby & Kriss), or 3545 (King)

Substituting first in formula 2 we have

$$D=\frac{H}{.01848\,NV+h}, \text{ or}$$

$$D=\frac{111120}{(.01848 \times 40 \times 3452)+634}=35.0 \text{ degrees}$$

From this computation it seems evident that a temperature difference of 35 degrees can be maintained in a well-built stable when large cows are kept at a maximum production and the wall space per cow is not above 46 square feet.

If small Jersey cows in low production were kept in this same stable, the temperature difference would be considerably reduced owing to the reduction in the amount of heat produced. It could be determined by using the same formula and substituting the new value for H.

$$D=\frac{80800}{(.01848 \times 40 \times 3452)+634}=25.5 \text{ degrees}$$

In this case the temperature could not be kept above freezing in zero weather without reducing the flow of air and thereby increasing the carbon dioxide content. The flow of air that could be allowed the Jersey cows and still expect them to maintain a temperature difference of 35 degrees, or the same D as was held by the Holsteins, can be determined by using formula 3 where

$$V=\frac{H-Dh}{.01848\,D\,N}, \text{ or}$$

$$V=\frac{80800-(634 \times 35.0)}{.01848 \times 40 \times 35.0}=2265 \text{ cubic feet per hour.}$$

The reduction in air circulation in this case would be equivalent to 3452 — 2265= 1278 cubic feet per hour per cow, and would raise the volume of air in the stable once breathed from 3.3 to 5.1 per cent, thereby raising the carbon dioxide content from .167 volume to .245 volume per cent.

From the foregoing computations it is evident that when Holsteins in high production are housed in a stable of this sort it will be reasonable to expect them to maintain a temperature above freezing in zero weather and at the same time maintain adequate ventilation conditions. On the other hand, if Jerseys in low production are housed, the stable temperature will drop below 32 degrees as soon as the outside temperature goes below 6 degrees above zero if the same rate of air flow through the stable is maintained. The air flow will have to be reduced over 1200 cubic feet per cow per hour in order to keep the inside temperature up. This will have the effect of lowering the ventilation standard a very considerable amount. Instead of 3.3 per cent of air once breathed there will be 5.1 per cent. Instead of 16.7 parts per 10,000 of carbon dioxide there will be present in the air 24.5 parts, an increase of approximately 33 per cent. Just how serious such a condition will be to the cows is questionable. It is probable that they will not suffer sufficiently to warrant the installation of a heating plant to make up the heat deficiency because such a condition will last only as long as the temperature remains around zero, and such will probably not be the case for long periods of time.

It can be shown by the use of formula 2 that small Jersey cows on maintenance alone can maintain a temperature difference of from 15 to 17 degrees in well-constructed stables. This is probably the smallest heat-producing plant that need ever be designed and it would occur only very rarely. In the large majority of stables the cows will be in part at least producing some milk and therefore additional heat, and it is probably correct to state that for average conditions the smallest temperature difference that will ever be a maximum will be 20 degrees. In a large number, perhaps the great majority of cases, the maximum possible temperature difference that can easily be maintained will be above 25 degrees and in some cases will run up to 35 degrees or more. (By maximum temperature difference is meant that which can be maintained compatible with an air flow of 3452 cubic feet per hour per cow unit.) Of course, during cold periods the temperature inside can be kept above freezing at the expense of air purity as has been shown.

This being the case it is not unreasonable to assume that outtake flues may be designed to pass the required amount of air through a stable at a minimum temperature difference of 20 degrees. At smaller temperature differences, the ventilation system need not be expected to operate because air can then be supplied through doors and windows without danger of lowering the temperature of the stable below freezing.

Additional draft caused by wind blowing over the top of the flue should not be counted on to increase the air circulation in the stable over and above what will occur as a result of the maximum allowable temperature difference, because obviously any increase in the rate of air flow through the stable will have the effect of lowering the temperature. If, therefore, it is desired to maintain the temperature difference constant throughout alternate periods of high wind and no wind, it will be necessary to dampen down the flue (decrease its effective sectional area) while the wind is blowing, thus nullifying this effect.

Flues designed to pass the proper amount of air through the stable at 20 degrees temperature difference without the addition of motive power due to a wind over the top, will be efficiently operative at the time when draft producing power is at a minimum. They should be provided with dampers to reduce their section at such times as the temperature difference increases or the wind is blowing thus preventing an unnecessarily high rate of flow through them. The checking of the air flow through a stable can be accomplished by means of such dampers on the outtakes, or else by means of dampers on the inside ends of the intakes. Objection has been taken to the former method on the score that the operator is usually inclined to close the damper too far thus choking the flue and rendering it comparatively ineffective; and further, that there is a natural human tendency to forget to open them again when the temperature difference decreases.

It is claimed that the more effective point of control is at the inside end of the intake for several reasons. First, there is a tendency for some intakes to back draft, and it is still questionable whether this can be overcome although a device will shortly be on the market for which such claims are made. This being the case, the checking of back drafting and of air flow can both be performed at the same time and by the one operation of closing all of the back drafting flues and some of those that are operating correctly. Second, it is not possible to check the air flow so rapidly or completely by closing the intakes because to some extent the air that is prevented from coming in one intake will come in some of the

others that are still open. In other words, closing one or two intakes has the effect of increasing the velocity of air in all the others, assuming that the outtakes have the same adjustment in each case.

It is very probable that a combination of both methods of checking will prove most satisfactory for the careful man who has the best interests of the stock at heart.

Having attempted to establish the reasonableness of 20 degrees as a temperature difference to be used in design, let us consider the problem of determining the proper size of flue for a given set of conditions.

In the accompanying drawing let H equal the height of a foul air flue in which, if there were no temperature difference, the column of air would be exactly balanced by an equal column of outside air entering the stable at the ceiling. Suppose now that the air in the flue becomes warmed to a temperature of T degrees, the outside temperature remaining at t degrees. The flue air will expand a definite amount depending upon its absolute temperature before and after warming, and in its rarified condition would require a column equal to h in addition to its original volume to balance exactly the original outside column. In other words, the weight of an outside column of air equal in volume to v would, acting under gravity, through a head equal to h be the force producing an upward flow in the flue, disregarding friction for the moment.

The volumes of these columns are proportional to their heights, therefore,

$$H : H + h = V : V + v$$

Also the volumes are proportional to the absolute temperatures before and after warming. Thus

$V : V + v = 460 + t : 460 + T$

Hence, $H : H + h = 460 + t : 460 + T$.

(1) Algebraically, $h = \dfrac{H\,(T - t)}{460 + t}$.

The formula to determine the velocity of falling bodies is (2) $v = \sqrt{2\,g\,h}$

Considering air as the falling body and h in the figure the distance through which it falls, or its head, we can substitute its value in the velocity formula, from which we see that

$$V = \sqrt{\frac{2\,g\,H(T-t)}{460+t}}$$

and $$V = \sqrt{\frac{8.02\,H\,(T-t)}{460 + t}}$$

We have already seen that 20 degrees will be a reasonable temperature difference for which to design and we can further assume with propriety that in time when the system is first expected to operate in the fall will be when t, the temperature outside, is just about or slightly below freezing. Substituting these values in the formula we have

$$V = \sqrt{\frac{8.02\ 20\ H}{460 + 30}} = 1.71\sqrt{H}$$ feet per second, or

(3) $V = 60 \times 60 \times 1.71\sqrt{H} = 6156\sqrt{H}$ feet per hour.

If air were passing through a 12-by-12-inch flue at the rate of V linear feet per hour, then the rate at which air would be drawn from a room through it would be V cubic feet per hour, neglecting friction in the flue. V can, therefore, be stated as the rate of change of air in cubic feet per hour through a one foot square flue, thus

(4) $V = 6156\sqrt{H}$ cubic feet per hour through 12-by-12-inch flue.

It has been customary in the past to assume that the actual flow of air through a flue as ordinarily installed in a barn would be one-half the theoretical flow, although this amount of variation will undoubtedly differ in flues of different shapes, length and construction. Lacking any other definite figures resulting from authentic experimentation, however, and in view of the fact that up to the present this "factor of safety" has proved adequate it will be retained here, and being incorporated into formula 4 makes it read.

(5) $V = 3078\sqrt{H}$ cubic feet per hour through a 12-by-12-inch flue.

If the cow capacity of the stable is known, the amount of air to be passed through each hour can be found by simply multiplying the rate per cow by the number of cow units, thus (6) Total air flow per hour $= 3452\,N$, where N = number of cow units of stable capacity.

If formula 5 states the rate of change through a 12-by-12-inch flue and formula 6 states the total rate of change required, then obviously the number of square feet of total flue area required can be found by dividing formula 6 by formula 5, thus

(7) $A = \dfrac{3452\,N}{3078\sqrt{H}}$ = square feet of flue area required for the stable.

But it is desirable, in order to simplify later computations, to have this area stated in square inches rather than square feet. This can be accomplished by multiplying formula 7 by 144, thus

(8) $A = \dfrac{144 \times 3452\,N}{3078\sqrt{H}}$ = square inches of flue area required for the stable.

Bringing this formula to its simplest form it becomes

(9) $A = \dfrac{162\,N}{\sqrt{H}}$ = square inches of flue area required for the stable, in which

N = number of cow units stable capacity, and

H = difference in elevation in feet between the point where the fresh air enters the stable and the point where the foul air leaves the outtake flue.

It is evident then that, in order to use this formula, it is necessary to know only the number of cows or cow units that the stable is capable of housing and the height of the ridge of the roof above the ceiling of the stable in the case of the King system, and above the floor of the stable in the case of the Rutherford system. The results will be a statement of the total flue area required and not of the number of flues. This must be determined by the designer to suit the individual requirements of the case, and inasmuch as these requirements may present almost infinite variations, no definite rule can be laid down. In general, however, it has been found good practice to place flues not farther apart than 30 feet and to have them in opposite pairs, each pair outletting through one ventilator head on the ridge.

The use of this formula should be strictly reserved for cases where the air space per animal housed does not run over 1000 cubic feet, because in such a case there is not sufficient animal heat to maintain the temperature difference designed for. This would exclude calf barns and maternity stables in which the plan consists of a series of box stalls.

Agricultural Engineering Development

A Review of the Activities and Recent Progress in the Field of Agricultural Engineering Investigation, Experimentation and Research

Edited by **R. W. Trullinger**

Mem. A.S.A.E. Specialist in Rural Engineering, Office of Experiment Stations, U. S. Department of Agriculture

QUALITY OF IRRIGATION WATER IN RELATION TO LAND RECLAMATION, C. S. Scofield and F. B. Headley, [*Journal of Agricultural Research*, (U. S.) Washington, D.C. 21 (1921), No. 4, pp. 265-278.] Studies conducted by the Bureau of Plant Industry of the U. S. Department of Agriculture on the action of irrigation waters, containing excessive quantities of silt, on soils are reported and discussed.

Attention is drawn to certain irrigated soils which are impervious to water and become hard and difficult to work when dry. As a result of the present investigation the conclusion is reached that the trouble with these soils is not due to sodium carbonate exclusively, but that it may be induced by the so-called neutral salts of sodium as well. When soils containing excessive quantities of sodium chlorid or sodium sulphate were leached with pure water, similar results were produced as when such soils were irrigated with water containing sodium carbonate.

It was also found that this injurious effect of sodium salts is much reduced if the salty soil is first leached with a solution of some salt of calcium or aluminum. A soil so treated may be subsequently leached with pure water without developing the symptoms of a reduced permeability and an alkaline percolate. If the irrigation water contained calcium salts equal to or in excess of the sodium salts, the soil rendered salty by such water was less likely to become impermeable when subsequently leached with pure water or with water containing these salts in the same proportion but in lower concentrations.

The further conclusion is drawn that the quality of irrigation waters should be judged not only by considering the total quantity of the salts in solution or the proportions of the acid radicals, but also the proportion of the sodium to the calcium and magnesium. It is suggested that water, to be safe for long-continued irrigation, should be relatively rich in calcium and magnesium.

CARBON DIOXID CONTENT OF BARN AIR, M. F. Hendry and A. Johnson. [*Journal of Agricultural Research* (U. S.), Washington, D. C., 20 (1920), No. 6, pp. 405-408.] Determinations of the carbon-dioxid content of the air in the dairy barn at the New Hampshire agricultural experiment station are reported.

These studies were conducted in connection with the construction and establishment of a respiration chamber for large domestic animals in the barn at the station. The barn is well lighted and apparently well ventilated. The stock room is approximately 100 feet long, 35 feet wide, and 8 feet 8 inches high. It is provided with windows on both sides and has a concrete floor. The ventilating ducts withdraw the air from near the floor, and outdoor air can blow in on either side through screened openings.

The studies consisted solely of gas analysis made in connection with the possibility of leakage of barn air into the respiration chamber. It was found that on the average the amount of carbon dioxid in the barn air is not far from eight to ten times the normal carbon-dioxid content of outdoor air. The samples were taken at regular intervals during the day and night at fifteen different locations at the front and in the rear of the animals. Of the fifteen different locations, 1 to 5, as shown in the following table, were in the feed alley between the two rows of stalls and therefore in front of the animals. Locations 6 to 15 were in the two outer alleys and therefore at the rear of the animals. All samples were taken approximately 4 feet from the floor.

CARBON DIOXID IN AIR OF BARN AT DURHAM, N. H., DURING JANUARY AND FEBRUARY, 1919

[1] This position was nearest the respiration chamber.

Time of Day	Location	Percentage Carbon Dioxid
8:50 a.m.	1. Beginning of feed alley	0.228
do	2. Feed alley, about 15 feet from No. 1	.225
do	3. Center of feed alley	.214
do	4. Feed alley, about 15 feet from No. 3	.228
10:05 a.m.	5. End of feed alley	.194
do	6. Beginning of right-hand outer alley[1]	.106
do	7. Outer alley, about 15 feet from No. 6	.089
do	8. Center of right-hand outer alley	.098
11:00 a.m.	9. Outer alley, about 15 feet from No. 8	.101
do	10. End of right-hand outer alley	.097
do	11. Beginning of left-hand outer alley	.107
do	12. Outer alley, about 15 feet from No. 11	.089
11:40 a.m.	13. Center of left-hand outer alley	.162
do	14. Outer alley, about 15 feet from No. 13	.116
do	15. End of left-hand outer alley	.115
4:45 p.m.	1. Beginning of feed alley	.149
5:20 p.m.	2. Feed alley, about 15 feet from No. 1	.219
5:30 p.m.	3. Center of feed alley	.207
5:00 a.m.	1. Beginning of feed alley	.177
10:30 p.m.	do	.132
5:00 a.m.	do	.109
do	do	.101
9:30 p.m.	do	.211
11:30 p.m.	3. Center of feed alley	.102
5:00 a.m.	do	.211
10:40 p.m.	do	.187
5:00 a.m.	do	.167
11:30 p.m.	do	.184
5:00 a.m.	do	.130
11:20 p.m.	do	.139
5:00 a.m.	do	.168
11:15 p.m.	do	.178
5:00 a.m.	do	.094
11:50 p.m.	do	.209

The data show that the carbon dioxid percentages found varied from 0.228 to 0.089. It is noted in this connection that the percentages found by the Committee on Farm Building Ventilation of the American Society of Agricultural Engineers in 1918, from studies of five barns, were as high as 1.231, but for the most part were not higher than from 0.2 to 0.3. Owing to the excellent health of the animals in the barn, it is concluded that carbon dioxid even in percentages from 8 to 10 times the normal percentage has no serious effect upon the animals.

THE TRANSMISSION OF HEAT THROUGH SINGLE-FRAME DOUBLE WINDOWS, A. N. Shaw. [*Journal American Society Heating and Ventilation Engineers*, New York, 26 (1920), No. 9, pp. 773-786, figs. 9.] Approximate preliminary calculations on the transmission of heat through single-frame double windows show that the quantity of heat transmitted is about half a B. t. u. per square foot per hour per degree Fahrenheit difference, that the variation of this quantity with the thickness of the window is small, and that in the particular case of ½ and ¾-inch windows the difference should be less than 5 per cent.

Ten experimental determinations of the actual transmission of heat through ¾ and ½-inch single-frame double windows led to the final conclusion that these sizes will transmit between 0.6 and 0.7 B. t. u. per square foot per hour per degree Fahrenheit difference and that the percentage difference for the two sizes will be less than 2.5 per cent. A description is given of the apparatus used in conducting these experiments, and the theory forming the basis of the experiments and methods of procedure is outlined.

THE NEBRASKA TRACTOR LAW AND RULES FOR OFFICIAL TRACTOR TESTS, O. W. Sjogren, E. E. Brackett, C. W. Smith, and F. R. Nohavec. [Nebraska Station (Lincoln) Circular 13 (1921), pp. 8, fig. 1.] This is a revision of Nebraska Agricultural Experiment Station Circular No. 10. It contains the text of the Nebraska tractor inspection law, describes the procedure and equipment in conducting the tests, and gives the rules for, and a detailed description of the tests.

EXPERIMENTAL SEWAGE IRRIGATION PLANT IN FLORIDA, F. E. Staebner, [*Engineering News-Record*, New York, 85(1920), No. 18, pp. 848, 849, figs. 3.] The details of an experimental sewage irrigation plant designed by the Florida agricultural experiment station, in cooperation with the U. S. Department of Agriculture, are presented in this report.

The plant utilizes the sewage from the University of Florida, and the original plant consisting of a septic tank and a broken stone filter bed has been retained. The tank gives a rather clear effluent which is discharged on to the filter bed through four aerating sprays controlled by an automatic siphon operating at 30-minute intervals. A diversion box was built in the filter bed outlet to deliver the water to the irrigation field. In normal operation the effluent runs by gravity from the filter bed to the diversion box, and thence through an inverted siphon to a reinforced concrete collecting tank from which it is pumped by a motor-driven centrifugal pump to the irrigation field 400 feet away. The water is discharged successively through any one of eight automatically operated valves to a small head ditch at that valve, from which it flows over wooden weirs into the furrows between the crop rows. The 1920 crops were corn, sorghum, and Japanese cane.

So far 1.6 acres have been irrigated, applying from 25,000 to 30,000 gallons of sewage per day. The soil is sandy loam and tends to be very dry, and so far a thoroughly sanitary disposal has been secured. It is noted that the water runs a distance of from 175 to 350 feet down the furrows according to the dryness of the land.

Further experiments indicated that allowing the sewage water to run down every other furrow is as effective agriculturally as allowing it to run down every furrow.

THE CARBURETION OF ALCOHOL, A. W. Scarratt. [*Journal of the Society Automotive Engineers*, New York, 8 (1921), No. 4, pp. 328-330, figs. 2.] The results of experimental work on the development of a tractor engine that will burn alcohol are reported.

Using a 4¼-by-6-inch, four-cylinder, 16-valve engine, it was found that the best compression was 110 pounds per square inch. It was necessary to use the entire exhaust heat for heating the fuel charge, and to maintain the temperature of the ingoing charge of fuel for good carburetion and economical operation at not less than 100 degrees Fahrenheit. The results indicated that the intake manifold should be designed to obtain uniform distribution, and the intake manifold gas velocity at full load should not be less than 9,500 feet per minute on the average.

Starting difficulties were increased when burning alcohol, but satisfactory starting was accomplished by a redesign of the starting crank, together with the use of a mixture of four parts of alcohol to one of gasoline.

SUBSOILING EXPERIMENTS AT THE EDGELEY SUBSTATION, O. A. Thompson, [North Dakota Station Agricultural College, Bulletin 145 (1921), pp. 21, 22.] Data on experiments in subsoiling and packing the land as methods of preparing the soil for durum and hard wheat, oats, and barley are reported and summarized in the accompanying table. It is the plan of this experiment to subsoil the land once every four years in the subsoil plats and to fall plow the land 6 inches deep in all plats the remainder of the time. The subsoil plats are plowed 6 inches deep at the time of subsoiling. A continuous cropping system is practiced. The average of six years' trials indicates that packing and subsoiling has been of no benefit. Good 6-inch plowing has given as good yields as were obtained with 6-inch plowing plus subsoiling and 6-inch plowing plus subsoiling and packing.

SUBSOIL EXPERIMENTS—1912-1917

Method of Cultivation	Durum Wheat							Hard Red Spring Wheat (Fife)						
	1912 Bu.	1913 Bu.	1914 Bu.	1915 Bu.	1916 Bu.	1917 Bu.	Average Bu.	1912 Bu.	1913 Bu.	1914 Bu.	1915 Bu.	1916 Bu.	1917 Bu.	Average Bu.
Plowed 6 inches deep	30.0	21.3	14.0	21.3	6.6	5.0	16.4	23.0	17.3	5.0	21.0	6.0	5.3	12.9
Plowed 6 inches deep, subsoiled	30.7	19.3	15.0	24.3	5.3	4.7	16.6	27.0	16.0	5.7	18.6	6.0	3.3	12.8
Plowed 6 inches deep, subsoiled, packed	30.7	18.3	16.3	19.6	7.0	7.0	16.5	27.0	15.3	7.0	15.3	6.3	5.6	12.8

Method of Cultivation	Oats							Barley						
	1912	1913	1914	1915	1916	1917	Average	1912	1913	1914	1915	1916	1917	Average
Plowed 6 inches deep	43.1	24.4	45.0	53.8	30.0	18.7	35.8		22.2	26.6	29.8	16.6	3.8	19.8
Plowed 6 inches deep, subsoiled	55.6	21.9	44.3	51.9	30.5	11.9	36.0		20.2	27.0	28.5	15.0	3.3	18.8
Plowed 6 inches deep, subsoiled, packed	48.8	18.8	39.3	48.8	30.0	13.1	33.1		20.2	24.1	31.5	15.0	1.7	18.5

WIRE BELTS WITH PAPER DRIVING SURFACE, H. Mittermayr. [*Zeitschrift des Vereines Deutscher Ingenieure*, Berlin, abstract in Science Abstracts, Section B,—Electrical Engineering, New York and London, 23 (1920), No. 266, pp. 79-81, figs. 2.] Belts are described consisting of flat-wound wire spirals with alternately right and left-hand lead coupled together by cross pins. Paper yarn is wound between the spirals, giving the belt a soft running surface and securing the adhesion required for power transmission.

Tests were made to determine the capability of these belts to transmit the same power as leather belts when running on the same pulleys. The tests showed no appreciable slip between belt and pulley until the load became excessive. Three degrees of slipping were then observed, namely, slight waves, sharp flickering movements, and a swinging of the whole span of the belt. A little wax increased the power transmitted by the belt, but an excess caused unsteady running by accumulating on the pulley. It was found that the possible power transmission increased with the distance between axes, which must not be less than a certain minimum if favorable conditions are to be obtained. About the same transmission was obtained with wooden pulleys as with iron pulleys. Thicker belts of this construction employed coils of greater pitch and relatively smaller adhesion surface, so that the permissible belt tension per inch width increased slowly or even decreased with increasing belt thickness.

The maximum permissible tension in pounds per inch of belt width for a belt of medium thickness was found to vary approximately as shown in the following table:

PERMISSIBLE BELT TENSION PER INCH WIDTH

	Belt Speed—Feet Per Second			
	6.56	19.685	39.37	59.055
Pulley Diameter—Inches	Tension—Pounds Per Inch			
7.8742	81.20	74.48	70.56	67.200
19.6853	112.00	103.04	96.32	91.280
31.4966	133.28	122.08	113.12	106.960
59.0561	161.28	145.60	133.28	123.200

Lower values of tension must be used for inclined or vertical drives or if the distance between pulley centers is unduly short. These belts are said to be particularly suitable for slow drives, large pulleys, and long spans, and can be substituted directly for leather belts of the same width and will transmit considerably more power than leather. However, they lack the elasticity of leather.

A RECENTLY DEVELOPED DUST EXPLOSION AND FIRE HAZARD, D. J. Price and H. R. Brown. [U. S. Department of Agriculture, Washington, D. C., Circular 171 (1921), pp. 7, fig. 1.] Studies of the relation between improper installation and inadequate protection of incandescent lamps to the fire and dust explosion hazard in dusty industries, conducted by the U. S. Department of Agriculture, are reported.

In the preliminary experiments it was found that a 32-candlepower electric lamp ignited coal dust in less than 30 minutes and a 16-candlepower electric lamp in 32 minutes.

Experiments to determine whether or not the exposed filament in a broken electric lamp will remain hot long enough after the globe is broken to ignite a surrounding dust cloud were next conducted. The tests were made in an explosion chamber fitted with a socket to hold lamps of various sizes and a rod with trigger release to smash the lamps. A dust cloud was produced by blowing dust from small shelves along the side of the chamber. Explosions were obtained with both vacuum and gas-filled lamps. The only exceptions were with vacuum tungsten and carbon lamps of very low wattage. It is concluded, therefore, that dust explosions and fires can be caused by the breaking of an electric lamp in a dust cloud.

Tests were also conducted to ascertain the danger due to the ignition of dust which will settle on a lamp globe. Temperature readings of the various types of vacuum and gas-filled lamps on the market were compared with the ignition temperatures of various combustible dusts found in industrial plants. It was found that the temperature of the dust must be raised at least 150 degrees Fahrenheit above the maximum temperature of the bulb to cause ignition.

In a specially constructed chamber in which a continuous dust cloud was maintained, it was found possible to start a fire on the larger gas-filled lamps with each of four carbonaceous dusts. These dusts were as follows: (1) An approximate mixture of 22 per cent oats, 20 per cent durum wheat, 40 per cent winter wheat, 10 per cent hard winter wheat, and 10 per cent miscellaneous dusts, (2) durum wheat dusts, (3) a mixture of approximately 40 per cent winter wheat, 35 per cent barley, and 25 per cent oats dusts, and (4) a mixture of approximately 60 per cent oats, 35 per cent winter wheat, and 5 per cent rye dusts.

It is concluded from these results that any combustible dust if allowed to collect on a lamp in sufficiently thick layers and remain long enough will ignite. Methods for fire and explosion prevention are discussed.

THE COMBUSTION OF FUELS IN THE INTERNAL-COMBUSTION ENGINE, T. Midgley, Jr. [*Journal of the Society of Automotive Engineers*, New York, 7 (1920), No. 6, pp. 489-497, figs. 18.] The author deals briefly with the organic chemistry of internal-combustion engine fuels, and reviews the results of considerable research into the combustion of fuels in internal-combustion engines, with particular reference to the phenomenon of knock. The opinion is expressed that knock is due to detonation of the gas charge in a cylinder.

Fuel studies to determine the order of their tendency to knock showed that the ethers are the worst knockers, followed by the paraffins, which include the fuels in common use. These are followed in order by the olefins, the naphthenes, aromatics, and alcohols.

The theory of knock suppressors is also discussed.

CONCRETE IN ALKALI SOILS AND WATERS, A. S. Dawson. [*Journal Engineering Institute*, Montreal, Canada, 3 (1920), No. 10, pp. 476-480, p. 22.] A progress report on the subject is presented, in which a discussion of the origin of alkali salts and their action on concrete is followed by the results of laboratory and field tests of concrete cylinders made from two different cements.

The results to date show that laboratory test cylinders are all relatively lower in strength than field test specimens because of the difficulty in maintaining a uniform degree of moisture. The most disintegration of specimens was found at locations of greatest concentrations of soil solutions. In a concrete of high density the action appeared to be relatively slow and was largely in the nature of surface action, gradually extending to the interior. In relatively porous concrete the action was more rapid and apparently took place simultaneously throughout the structure. The more porous concrete was also found to be subject to the action of other disintegrating forces of a physical nature, such as frost and the crystallization of salts in the pore spaces. A dense concrete mixture resulted in greater resistance to alkali action, this being true for both 1:1½:3 and 1:2:4 mixtures. The presence of alkali soil solutions did not retard the setting of the cement and no difference was apparent between the different cements used.

The experiments are being continued.

PLOWING EXPERIMENTS AT THE EDGELEY SUBSTATION O. A. Thompson. [North Dakota Station Agricultural College Bulletin 145 (1921), pp. 20, 21.] The results of eight years' experiments in different methods of preparing land for crops are presented and are summarized in the accompanying table. It is noted that crops on the early fall-plowed land gave the best yields, those on spring-plowed land second, and those on medium and late fall plowing third. There appeared to be no advantage obtained from packing the land either in the fall or in the spring for cereal crops. The indiscriminate use of the subsurface packer is therefore not recommended. A comparison of the average yield from all the fall methods of tillage with the average from all the spring methods shows a difference of 3.2 bushels of wheat per acre in favor of the latter.

It is noted that the crop did not respond to deep plowing on the light sandy soil on which the tests were conducted as it might have on heavier land.

PLOWING EXPERIMENTS 1909-1917*

	METHOD OF PREPARING	Depth of Plowing, Inches	Yields of Arnautka Durum Wheat								8-Year Average Yield
			1909 bu.	1910 bu.	1912 bu.	1913 bu.	1914 bu.	1915 bu.	1916 bu.	1917 bu.	
1	Early fall plowed	5	22.8	3.9	22.0	24.0	10.2	25.0	7.8	4.8	15.0
2	Medium fall plowed	5	19.1	1.4	17.8	11.3	10.2	21.5	5.3	4.6	11.4
3	Medium fall plowed and packed in fall	5	19.8	1.3	20.0	10.8	8.5	21.3	6.0	4.3	11.5
4	Late fall plowed	5	20.1	1.0	17.3	11.5	7.7	19.2	4.1	4.8	10.7
5	Medium fall plowed	8	20.0	1.0	14.8	12.5	9.8	25.0	6.1	3.8	11.6
6	Medium fall plowed—fall packed	8	21.0	1.6	14.7	13.3	8.5	23.3	5.0	4.1	11.4
7	Spring double disked, fall-plowed in alternate years	5	19.6	1.2	14.8	12.3	8.3	15.7	5.0	6.3	10.4
8	Fall plowed, spring double disked in alternate years	5	21.3	1.5	17.3	14.8	7.7	19.3	5.3	5.8	11.6
9	Spring plowed—spring packed	8	23.0	2.7	23.6	22.3	11.3	23.8	3.5	8.0	14.8
10	Spring plowed	8	26.3	3.3	20.6	19.6	11.3	27.3	5.0	5.3	14.8
11	Spring plowed	5	25.1	3.6	22.6	18.3	9.5	25.3	5.0	10.3	15.0
12	Spring plowed, fall double disked in alternate years	5	29.1	3.7	24.5	17.5	10.5	22.1	4.3	8.5	18.8
13	Fall double disked, spring plowed in alternate years	5	29.0	7.7	30.5	21.6	13.6	22.5	5.1	7.3	17.2

*1911 crop a failure.

NITRATE CONTENT OF CERTAIN WATERS CONSIDERED BACTERIOLOGICALLY SAFE, M. S. Nichols. [JOURNAL INDUSTRIAL and ENGINEERING CHEMISTRY, New York, 12 (1920), No. 10, pp. 987—989.] Studies conducted at the University of Wisconsin of 808 bacteriologically pure waters are reported, from which the conclusions are drawn that an excessive quantity of nitrate nitrogen is not a normal component of ground waters safe for drinking purposes, and that a water containing five or more parts per million of nitrate nitrogen should be considered as a potentially dangerous supply until a sanitary survey can be made by a competent person. It is further concluded that the nitrate-nitrogen determination should be included in every ground-water examination.

POISONOUS GASES FROM CARBON TETRACHLORID FIRE EXTINGUISHERS, A. C. Fieldner, S. H. Katz, S. P. Kinney, and E. S. Longfellow. [*Journal Franklin Institute*, Philadelphia, 190 (1920), No. 4, pp. 543-565, Fig. 5.] An investigation of the decomposition products resulting from the use of carbon tetrachlorid fire extinguishers is reported.

Two methods of experimentation were used. The first consisted in applying the liquids from such fire extinguishers to actual fires and to hot metal in a closed room of 1,000 cubic feet capacity where the gaseous products, mixed with air, could be retained and analyzed. The second method consisted in passing the vapors in air through heated tubes of iron or quartz where the humidity of the air and the temperature could be controlled.

It was found that phosgene, which is intensely poisonous, was formed in toxic quantities in the gas chamber. Chlorin was formed in smaller amounts. Hydrogen chlorid gas was also formed. A considerable amount of carbon tetrachlorid vapor, which is a dangerous anaesthetic, also remained in the chamber. The experiments with the heated tubes confirmed the results obtained with actual fires.

As a result of these experiments it is recommended that carbon tetrachlorid fire extinguishers be not used on fires in closely confined spaces where conditions are such that the user cannot escape without breathing the fumes. (This recommendation is of special importance in the consideration of apparatus for fire fighting and prevention in barns and grain storages.)

DUSTING COTTON FOR THE CONTROL OF THE BOLL WEEVIL, M. C. Tanquary and H. J. Reinhard. [Texas Station, College Station, Circular 29 (1921), pp. 9, fig. 1.] Experiments conducted by the Texas agricultural experiment station in cooperation with the U. S. Department of Agriculture are reported, in which the dusting of cotton was done with both hand and cart dusters. It was found that weevil infestation may be reduced from a high to a very low percentage by dusting with calcium arsenate when the poison is applied with efficient machinery. It is recommended that cotton farmers equip themselves with an approved type of dusting machine. It was found that the old pole and bag method is useless. One hand gun should be allowed for from 8 to 10 acres. And one two-horse cart duster for from 75 to 100 acres. The one-mule cart duster, a new type of machine is estimated to take care of about 60 acres.

A list of firms manufacturing cotton dusting machinery is included.

THE PENETRATION OF CREOSOTE IN VARIOUS SIZES OF SAWED LUMBER AND ROUND PILING, R. H. Rawson. [American Wood Preservers' Association Proceedings, 16 (1920), pp. 74-77, Fig. 4.] Mathematical and graphic data are presented on the relation existing between the shape of a piece of Douglas fir timber and the depth of penetration on treatment with a given amount of creosote oil. The formula for the penetration of creosote in various sizes of sawed lumber is derived and presented as follows:

$$t = \frac{\frac{b+d}{2} - \sqrt{\left(\frac{b+d}{2}\right)^2 - \frac{Pbd}{45.818}}}{2}$$

in which b, d, and t represent the width and depth of the lumber and the depth of penetrations in inches, respectively, and P represents the pounds of creosote per cubic foot of wood. A corresponding formula for round timber is presented as follows:

$$t = \frac{D - 2\sqrt{D^2 \Sigma \frac{PD^2}{45.818}}}{2}$$

in which D represents the average of the diameters at top and butt.

A. S. A. E. and Related Activities

Disk Harrow Investigation

IN THE April, 1921, issue of AGRICULTURAL ENGINEERING was published a progress report of the Committee on Disk Harrow Investigation of the American Society of Agricultural Engineers, the purpose of which investigation is to determine if it is feasible to eliminate the cutaway blade and standardize on the full blade for disk harrows. The subcommittee has continued its investigations during the past five months, and at a meeting of the plow and tillage implement department of the National Implement and Vehicle Association held in Chicago, October 12, the following summary of the work completed since the last progress report was presented to the plow and tillage implement manufacturers:

An exhaustive series of field tests have been made at the University of California and the following conclusions have been reached:

1. Cutaway blades penetrate better than full blades the amount varying with the soil.

2. Sixteen-inch blades penetrate better than eighteen-inch blades, the amount varying with the soil.

3. Cutaway blades require greater draft than full blades.

4. Sixteen-inch blades generally require greater draft than eighteen-inch blades. The draft increases nearly uniformly with the angle of set.

5. The draft of disk harrows does not increase with the speed as in the case of the plow. On the contrary, however, definitely noticeable decreases were observed between 0.4 and 6.1 miles per hour in one field. Considerably better pulverization was observed at the higher speeds.

Field tests made at the Iowa agricultural experiment station under various conditions show that the draft of the cutaway disks is on the average about fifteen per cent heavier than the draft of the full blade disk operated under identical conditions.

Questionnaires have been sent to dealers in the central states having had a considerable business in cutaway disk harrows and to a list of farmers furnished by these dealers. Only a few replies were received indicating that it is not a vital question to many.

Those who favor the cutaway blade make such claims as, (1) penetrates deeper in hard ground; (2) cuts stalks better; (3) harder to sharpen than the full blade but do not need sharpening as often; and (4) one dealer stated that he had full blades ground to the form of cutaway blades to meet the demand in his trade.

The disadvantages of the cutaway blade brought out in these questionnaires are: (1) Easily broken; (2) short lived; (3) only one-half of disk penetrates; and (4) causes the dealer and farmer trouble.

Since the outstanding feature of the cutaway disk is its ability to penetrate it would seem desirable to conduct field tests on hard ground conditions, comparing carefully the quality of work done by each type of blade. The subcommittee feels that the matter of penetration in hard ground is the most important problem it can work on. While the cutaway blade under the same conditions will penetrate deeper than the full blade, on the other hand, the cutaway blade will not work all the ground. For that reason the efforts of the committee from now on will be to determine which implement can produce the most satisfactory seedbed with the smallest amount of work on the ground. It was planned to make extensive tests this fall at the Iowa agricultural experiment station when the ground was baked hard, but these conditions had not existed at the time of making the report on account of too much rainfall. It is possible, however, that these tests will be conducted on ground that has been rolled down hard or on well-packed roads.

The subcommittee directing the disk harrow investigation consists of Prof. E. V. Collins, Iowa State College, chairman; Prof. C. I. Gunness, Massachusetts Agricultural College; E. J. Stirniman, University of California; Prof. A. E. Brandt, Oregon Agricultural College; and Prof. L. J. Smith, Washington State College.

Council Meeting

THE Council of the American Society of Agricultural Engineers held a meeting in the office of the president at Chicago, October 11. The members of the Council present were President E. A. White, Treasurer F. P. Hanson, I. W. Dickerson, W. G. Kaiser, and Raymond Olney.

The matter of Society finances occupied the chief attention of the Council during the meeting. Due largely no doubt to the present business and economic depression, quite a larger number of members are slow in paying their dues. This has handicapped in no small degree the work of the Secretary's office and made it impossible to meet certain obligations promptly. President White is writing a special letter to all members who have not paid their 1921 dues, urging that it is important to the best interests of the Society that payment be made promptly.

In connection with the subject of finances, the question of continued affiliation with the Federated American Engineering Societies was discussed. The sentiment of the Council members present was unanimous that this affiliation should, as a matter of present economy, be discontinued until the Society is in such position financially that reaffiliation with the F. A. E. S. seems justified.

It should be pointed out that potentially the Society is financially sound. The present financial stringency is not unlike that which is being experienced by thousands of business enterprises, but measures of economy and prompt payment of dues are quite essential to the well being of our organization at the present time.

Chairman I. W. Dickerson of the Meetings Committee presented a report of the tentative program for the annual meeting of the Society to be held at the Auditorium Hotel, Chicago, December 27, 28, and 29, 1921, which was discussed at considerable length. This year the Council in conjunction with the Meetings Committee has given a great deal of attention to the program for the annual meeting, and, as a result, a program is being worked that in interest, timeliness, and value to agricultural engineers promises to be far ahead of any that has ever been put on by the Society.

The Council has instructed the Secretary to give particular attention to the employment service activities of his office and, particularly, to give all the assistance possible to assist members out of employment to find satisfactory positions. This phase of the Society's activities will be enlarged as fast as conditions and facilities will permit.

The Council also discussed the matter of a Society exhibit at the national tractor show to be held at Minneapolis early in February. It is planned to have an exhibit similar to that of last year, and the departments of agricultural engineering at the various land grant colleges, as well as the division of agricultural engineering in the U. S. Department of Agriculture, will be asked to contribute to the exhibit.

The next meeting of the Council will be held in Chicago on December 26, the day previous to the opening of the annual meeting.

Employment Service

THE Secretary's office of the American Society of Agricultural Engineers has been able to render valuable service to a fairly large number of members of the Society in assisting them to find employment. The Secretary is making a special effort to assist all members who, in these extraneous times, find themselves out of employment to get in touch with individuals or organizations who are in need of the services which our members have to offer. Lists of positions open are on file at the headquarters of the Society, and in addition individual attention is given to helping each applicant find satisfactory employment. Those members desiring employment should file their names, qualifications, etc., with the Secretary. It is being planned at present to publish a list of positions open and men available regularly in AGRICULTURAL ENGINEERING beginning with the November number.

New Department of Agricultural Engineering at Virginia

DEMAND for agricultural engineering training in Virginia has become so great that the Virginia Agricultural and Mechanical College and Polytechnic Institute, Blacksburg, Virginia, has recently established a department of agricultural engineering. Courses are now being given to the regular agricultural students in farm structures, farm implements, agricultural drawing, graphic methods, farm power and machinery, and farm surveying and drainage. Other agricultural engineering subjects will be added next year.

Plans are being made to give a four-year course in agricultural engineering work next year. This course will be primarily for the agricultural student who wishes more engineering training than is secured by other agricultural students. The course will prepare him to handle, in an expert manner, all modern farm machinery and other problems of a practical engineering nature with which he will have to deal on the farm. It will also prepare him for selling and demonstrating agricultural equipment. A course in agricultural engineering, leading to an A. E. degree, will probably be added at a later date. This course will be arranged to meet the demand for engineers who are able to handle engineering problems pertaining to agricultural equipment. Sufficient training in the agricultural science will be given the engineering student to enable him to master the various problems of the farm, such as soil, drainage, machinery, building, etc. The subjects pursued will fit the man as a professional engineer to advise farmers with their problems, for the commercial field in producing, designing, and selling agricultural equipment, or for the educational field in college and school.

During the past year regular class work was given the agricultural college students in these various subjects and a number of gas engine and tractor short-courses were given during the summer months. A week's course was given to the Smith-Hughes agricultural high school teachers of the state with fifty of these teachers in attendance. A boys' farm mechanics short-course was given to the agricultural club boys of the state with an attendance of one hundred and twenty-seven. A two weeks' intensive short-course in engines and tractors was given to the vocational training men. Power-farming instruction was also given at the farmers' institute, which had an attendance of five hundred farmers. A number of short courses are being planned for the coming fall and winter months.

The personnel of the department is as follows:

Charles E. Seitz, head of department
J. S. Glenn, assistant
H. B. Boynton, assistant
H. B. Givens, mechanic

Present plans are to employ a full-time instructor and to put on a research man next year. Extension as well as resident instruction is being handled by the men in the department at the present time. The agricultural-engineering work is proving very popular in Virginia, and many applications have been received from prospective students for work in the agricultural-engineering department.

New Members of the Society

MEMBERS

C. D. Butchart, 1326-1330 Eleventh Street, Denver, Colorado.

G. R. B. Elliott, agricultural engineering department, University of Minnesota, University Farm, St. Paul, Minnesota.

O. G. Holway, city engineer, Chippewa Falls, Wisconsin.

Park Randall, Cle Internationale des Machines Agricoles, Croix (Nord), France.

E. A. Stewart, agricultural engineering department, University of Minnesota, University Farm, St. Paul, Minnesota.

F. S. Taylor, consulting engineer, Austin, Texas.

ASSOCIATE MEMBERS

A. J. McAdams, Court House, Marquette, Michigan.

E. M. Wilson, P. O. Box 844, Mexico City, Mexico.

JUNIOR MEMBERS

A. T. Holman, 124 East College Avenue, State College, Pennsylvania.

Applicants for Membership

The following is a list of applicants for membership received since the publication of the September issue of AGRICULTURAL ENGINEERING. Members of the Society are urged to send pertinent information relative to the applicants for the consideration of the Council prior to their election.

George Amundson, supervisor, Ashland County Land Clearing Association, Court House, Ashland, Wisconsin.

Harvey R. Burr, agricultural director, Williamson School, Delaware County, Pennslyvania.

G. G. Butterfield, draftsman, department of public works of the State of Nebraska, bureau of roads and bridges, Lincoln, Nebraska.

Jerry Donahue, president, The Jerry Donahue Engineering Company, Sheboygan, Wisconsin.

George E. Fuller, manager Power Farming Bureau, Chicago, Illinois.

Henry Gerbarz, president, Gerbarz-Jacqueth Engineering Company, Great Falls, Montana.

Samuel S. Graham, agricultural engineering department, Iowa State College, Ames, Iowa.

Alfred M. Hedge, salesman, Sun Company, Toledo, Ohio.

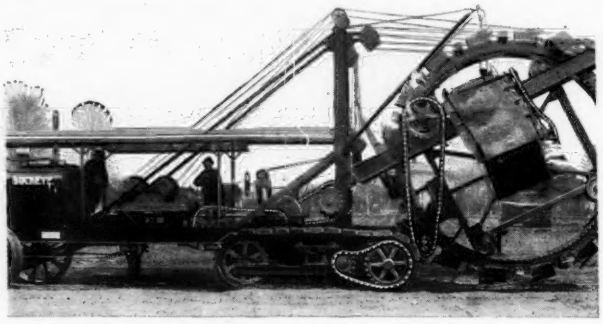
George E. Johnson, secretary and state engineer, department of public works, State of Nebraska, Lincoln, Nebraska.

S. P. Lyle, agricultural engineering department, Iowa State College, Ames, Iowa.

J. H. Mayne, Mayne Engineering Company, Council Bluffs, Iowa.

J. R. Rhyne, civil engineer, Corning, Arkansas.

H. B. Roe, associate professor of agricultural engineering, University of Minnesota, St. Paul, Minnesota.



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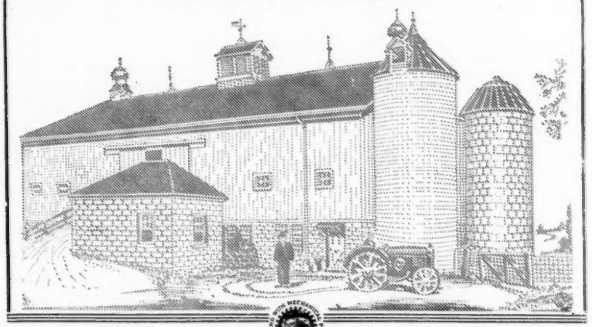

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